MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CLARK UNIVERSITY[1]

Communicated by EDWIN G. BORING

XXIII. THE SPATIAL CONDITION OF THE FUSION OF WARMTH AND COLD IN HEAT

By J. HENRY ALSTON

Heat, an introspectively unique quality, is conditioned upon the simultaneous stimulation of adjacent warm and cold spots. This theory derives from Alrutz, who obtained heat, a simple and unique quality, from a warm areal stimulus, adequate both to warmth and to paradoxical cold. Cutolo recently verified this conclusion with a more satisfactory technique. He stimulated an isolated cold spot with a cold stimulus, and simultaneously an adjacent warm spot with a warm stimulus of a temperature adequate to warmth but not to heat or paradoxical cold. In this manner he obtained qualitatively unique heats, and demonstrated further that heat actually does depend on the simultaneous excitation of cold and warmth, and not on the intensity of the stimulus. Neither stimulus of his cold-warm pair was alone adequate to heat; but simultaneously, when the cold stimulus was applied to the cold spot and the warm stimulus to the warm spot, they aroused the heat-quality.[2]

The phenomenon of heat bears directly upon physiological theory. If a unique quality, like heat, depends solely upon the coexcitation of two sensory spots that contribute ordinarily to different modalities of quality, then it is plain that the ascription of four modalities—pressure, pain, warmth, and cold—to the skin is psychologically inadequate, and that the concurrent assumption of four specific nerve energies is physiologically unsatisfactory. Whether or not ultimately we find the skin supplied with four separate afferent systems, we now know that we should not be able to regard such systems as acting in mutual independence; the completed psychology of the skin must take account of the interrelation of the excitations arising from the separate sensory spots. In the case of heat we already know that it depends upon the concurrent stimulation of adjacent warm and cold spots; hence we are ready to inquire further concerning the degree of adjacence that is necessary in order that a warm and a cold spot may act concurrently in the arousal of heat. With this question the present paper deals. If we find that excitations of warm

[1] In reviving with this paper Professor Sanford's series of Minor Studies from the Psychological Laboratory of Clark University the present director is sensible of the scientific standard that determined the publication of the first twenty-two studies and confesses to an ambition that the revived series may not fall below the ideal of its founder.

[2] F. Cutolo, A Preliminary Study of the Psychology of Heat, this JOURNAL 29, 1918, 442-448. Cutolo's historical orientation of the problem of heat, *q. v.* is too recent to require repetition.

and cold spots, remote from each other, may nevertheless fuse physiologically in yielding a simple heat, then we may infer an extensive interrelation of the thermal mechanisms and may perhaps guess even that the fusion is not peripheral.[3]

Our observers in this experiment were Dr. E. G. Boring (B), who was acquainted with the literature of the subject, who was highly trained in cutaneous introspection,[4] and had already served as observer in Cutolo's experiment; Mr. C. C. Pratt (P) and Mr. M. Yokoyama (Y), who were untrained in cutaneous observation but had had considerable general training in introspection.

In preliminary experiments P and Y were trained to recognize the quality of heat by the use of a heat-grill, patterned after Cutolo's.[5] B found that his familiarity with the nature of heat held over from his previous observation in Cutolo's experiment.

In the experiment proper we worked entirely with the punctiform stimulation of a two-point thermaesthesiometer.[6] Our instrument was constructed of two hollow pointed brass cylinders, through which water might circulate and which slid upon a graduated bar in such fashion that they could be set with their points at different distances apart. Each cylinder was 7.5 cm. in length, 1.2 cm. outside diam., and tapered to a point about 0.5 mm. diam. These cylinders were set at such an angle that the surface of their conical points nearest the skin made an angle of about 60° with the skin. One cylinder was connected with the supply of warm water and the other with the cold water faucet, in order that the instrument could be used to stimulate a cold spot with cold and a warm spot with warmth simultaneously. The warm water supply was kept at a temperature of 43-44° C. The supply-tub held about fifteen gallons and, with room temperature 20-22° C, varied less than 1° C in an hour. The cold water from the faucet during our period of experimentation varied between 5° and 10° C. The cold faucet and the tank of warm water were connected with the aesthesiometer through rubber tubing ⅛ in. inside diam. Each stimulus-cylinder of the aesthesiometer was provided with an inlet and an outlet, consisting of smaller tubes let into the side. The inlet was set at an angle of 45° with the side of the cylinder and directed toward its point; in this way we hoped to secure a good circulation at the stimulating point. The outlet emerged from the cylinder near the end remote from the point. The waste water from both outlets was led off through a Y-connection to a large

[3] It is not novel to consider the skin as a single sensory system of organs. Before Blix and Goldscheider, working under the inspiration of the theory of specific energies of nerves, had posited the four separate modalities, we had the *Gemeingefühl*, common sensibility; and after differentiation of tactile sensibility had begun there persisted the theory of pain as common sensation and Hering's theory of a single temperature sense. More recently there is Head and Rivers' conception of the epicritic and protopathic cutaneous mechanisms that cut across the orthodox modalities (*Brain* 28, 1905, 99ff.; 31, 1908, 323 ff.), and Titchener's suggestion of qualitative continua within and between the modalities of pressure and pain. (This JOURNAL, 31, 1920, 213 f.)

[4] *Cf.* E. G. Boring, Cutaneous Sensation After Nerve-Division, *Quart. J. Exper. Physiol.* 10, 1916, 1-95; esp. note, p. 4.

[5] *Op. cit.*, 446.

[6] Cutolo used the Zimmermann thermaesthesiometer, see Zimmermann *Liste 25*, 1912, Nr. 950.

rubber tube. The flow of water through each cylinder ranged from 1,000 to 1,200 cc. per min.

We worked entirely on the volar right forearm. The skin was laid out by a rubber stamp, 4x6 cm., divided into small coördinate squares, each 2 mm. on a side. The small separations of the stimuli fell within a single impression of this stamp; the wider separations required two or three adjacent impressions of the stamp upon the arm. The small separations were applied always in the middle of the volar surface and were longitudinally, transversely or diagonally directed according as the relative positions of the temperature spots determined. The greatest separations involved the greater part of the forearm and were therefore mainly longitudinal.

At every session, after stamping the arm, we mapped first for warm spots, which were the less numerous, and then for cold spots. We used the points of the thermaesthesiometer as stimuli in mapping. Since we did not obtain heat from the stimuli used separately in mapping, we were reasonably sure that heat, when it appeared for simultaneous stimulation, must be due to the concurrence of the two stimuli. Occasionally, in mapping, the warm stimulus did give rise to heat at some single spot; such spots were discarded.

After mapping, which usually required about twenty minutes, the experimenter proceeded to apply the dual stimulus,—a warm point to a warm spot and a cold point to a cold spot. The stimulus was put down with great care and every effort was made to place the two points upon the skin simultaneously. As a matter of fact, however, simultaneity of application has not the importance here that it has in determining the limen of dual impression for pressure. The tactual experience of the points is always felt an appreciable time before any thermal qualities arise. It is felt as "two," as "one," or as some intermediate pattern, depending presumably on the distance between the points. Most frequently the cold sensation arises first after the tactual impression and is followed later by a more complex perception (of warmth, or of heat, or of some concomitance of warmth, cold and heat).

The experimenter continued the application of the stimuli, until the observer reported a thermal quality or pattern, or until he was assured that no such pattern would appear. In most cases an application of ten seconds was sufficient to include the entire thermal experience.

After the removal of the stimulus the observer wrote an introspective account of the thermal perception.

Frequencies of Occurrence of Heat

In determining the relative frequencies of occurrence of the heat sensation and other thermal complexes, we have discarded entirely all trials in which no temperature at all was felt (heat, warmth or cold), in which cold was felt alone without heat or warmth, and in which warmth was felt alone without heat or cold. In other words, the term "total trials" (*cf.* Table I) is to be taken as the total of all trials in which heat occurred, whether alone or with warmth or with cold or with both, and of all trials in which warmth and cold occurred together without heat. All laboratory experience indicates that it is only under usual conditions of technique and for especially responsive spots that the method of stimulating a temperature spot with a metal point invariably gives a thermal response. When we failed, therefore, to get either heat or both cold and warmth as the

psychological evidence of simultaneous adequate cold and warm stimulation, we could not tell whether we were dealing with a failure of technique or whether we might actually be concerned with the case of inhibition of cold by warmth, or the converse, or, in the case where no thermal quality was felt, with a mutual inhibition. Our study, therefore, throws no light on the existence or nonexistence of inhibit-

TABLE I

Number of cases in which (1) a heat and (2) a simultaneous cold and warmth occurred for different separations of the aesthesiometer points. The percentages are percentages of the total number of trials reported by each observer (B, P and Y) for the given separation. The frequencies for heat include every case where heat was reported, whether alone or with cold or with warmth or with both. Cases occurring at the limit of a class-interval are counted in the upper group; *i.e.* 4 cm. is included in the group " 4-6 cm.", and "2-4 cm." means " 2 or greater but less than 4."

	Separation	Number of Cases			Per cent of Total Trials		
	cm.	B	P	Y	B	P	Y
1. Heat	0–2	38	32	54	.76	.89	.92
	2–4	34	21	23	.85	.81	.88
	4–6	27	12	20	.80	.86	.77
	6–8	19	21	15	.66	.78	.79
	8–10	18	6	9	.60	1.00	.43
	10–12	12	25	0	.34	.81	0
	12–15	9	12		.23	.63	
	15–18	2	2		.14	.29	
	18–20	0	0		0	0	
	Total heats	159	131	121	.58	.78	.73
2. Simultaneous cold and warmth	0–2	12	4	5	.24	.11	.08
	2–4	6	5	3	.15	.19	.12
	4–6	8	2	6	.20	.14	.23
	6–8	10	6	4	.34	.22	.21
	8–10	12	0	12	.40	0	.57
	10–12	23	6	14	.66	.19	1.00
	12–15	30	7		.77	.37	
	15–18	12	5		.86	.71	
	18–20	5	3		1.00	1.00	
	Total cold and warmth	116	38	44	.42	.22	.27
Total trials		275	169	165	1.00	1.00	1.00

ing effects between warmth and cold. We may note, however, that these apparent failures of technique were not numerous. B failed in this way in 12% of all trials; P in only 6%; and Y in 4%.

The principal result of our study is shown in Table I. This table shows the occurrence of heat as a function of the separation between

TABLE II

Number of cases in which were reported (1) a heat with a simultaneous cold, (2) a heat with a simultaneous warmth, (3) a heat with cold and warmth simultaneous, (4) a heat with cold or warmth or both cold and warmth simultaneous, and (5) a heat without any thermal concomitants. (4) includes all cases separately given in (1), (2), and (3). The percentages are percentages of the total number of heats reported by each observer for the given separation; see (1) in Table I. The class-intervals of separations are defined in the legend of Table I. Here class-intervals for which no cases occur are omitted from the table.

	Separation	Number of Cases			Per cent of Total Heats		
	cm.	B	P	Y	B	P	Y
1. Heat and cold concomitant	0–2	8		3	.17		.06
	2–4	10		2	.23		.08
	4–6	4		2	.13		.10
	6–8	4		4	.19		.03
	8–10	0		0	0		0
	10-12	2			.14		
	Total	28		11	.18		.09
2. Heat and warmth concomitant	0–2	3			.07		
	2–4	3		1	.08		.04
	4–6	2	1		.07	.08	
	6–8	4			.17		
	8–10	4		1	.18		.10
	10–12	2	1		.16	.04	
	12–15	2			.18		
	Total	20	2	2	.13	.02	.02
3. Heat, cold and warmth concomitant	0–2	1		1	.03		.02
	2–4			1	0		.04
	4–6	2		1	.07		.05
	6–8	2	1	4	.10	.05	.17
	8–10	3		1	.14		.06
	10–12	4			.25		
	Total	12	1	8	.07	.01	.08
4. Heat concomitant with cold or warmth or both	0–2	12		4	.32		.04
	2–4	13		4	.38		.17
	4–6	8	1	3	.30	.08	.15
	6–8	10	1	8	.53	.05	.53
	8–10	7		2	.39		.17
	10–12	8	1		.67		.04
	12–15	2			.22		
	Total	60	3	21	.38	.03	.19
5. Heat without thermal concomitants	Total	99	128	100	.62	.97	.81

the warm and cold spots which unite in the production of heat. A general trend is clear, although the columns of percentages fail to present uniform functions because of the fewness of the cases. When the stimulus-points are close together, heat is usually aroused although cases of simultaneous warmth and cold do occur for spots less than 2 cm. apart. As the separation between points is increased the heats become sooner or later less numerous and finally at a critical distance fall off rapidly in frequency. We find a maximal distance beyond which—in our few cases at least—no heats occurred. Y never felt heat for separations greater than 10 cm., and B and P never felt it for separations greater than 18 cm.[7] Although we did not determine for P and Y the limen of dual impression for pressure, it presumably should be about 3 cm. in the longitudinal direction.[8] B's limen for the corresponding region of the other arm is almost exactly 3 cm.[9] Thus it appears that warmth and cold may fuse into a qualitatively simple heat when the contributing stimuli are separated by a distance five times as great as the limen of dual impression for pressure.

In Table II we have noted the frequencies with which heat was reported as occurring concomitantly with cold or warmth or both. It will be noted that B reports such concomitants more frequently than Y (B 38%; Y 19%) and that P reports almost no concomitants at all (3%). It seems probable that these numerical differences are attributable to differences of attitude and training of the observers. B was highly trained in the observation of cutaneous quality and bore a critical attitude toward the experience of heat. He gave much more complete introspective analyses than P or Y. P on the other hand seems to have taken the attitude of searching for thermal *Merkzeichen;* in other words, he sought for typical and univocal thermal qualities. In the preliminary mapping for temperature spots, it was always more difficult to determine both the cold and the warm spots with P than with the other observers, a difficulty due, at least in part, to P's reluctance to make a positive report when he lacked the full realization of the *Merkzeichen.*

In view of these discrepancies and of the fewness of the cases, it is not possible to state whether the occurrence of concomitants is a function of the separation between the stimuli or not. B's results (*cf.* the fourth section of Table II) suggest that warmth or cold is simultaneously distinguishable from heat more often when the separations are large; *i. e.,* the appearance of warmth or cold, concomitant with the heat, gives promise of the disintegration of heat into warmth and cold that occurs at still greater separations.

Cold seems to appear as a concomitant with heat more often than warmth, and cold and warmth together appear least often as concomitants. The cases are again, however, too few for positive generalization.

It should be noted that we have not excluded the possibility that concomitance means attentive analysis. If heat were sometimes to break up under attention into warmth and cold, it would undoubtedly often be reported as concomitant with the warmth or cold or both.

---

[7] Y is 59 in. in height; B is 67 in.; P is 72 in. Czermak, supposing a constant number of cutaneous nerve-endings, held that children and small persons had a finer *Raumsinn* than large persons; *cf.* V. Henri, *Raumwahrnehmungen des Tastsinnes,* 1898, 38 f.

[8] *Cf.* C. L. Friedline, this JOURNAL 29, 1918, 404.

[9] Boring, *op. cit.,* 23.

It is peculiarly difficult for an observer to say, when attention turns from the heat to the warmth or cold, whether the heat lapses or whether it simply drops from the attentive focus to the margin. In the former case there would presumably be an alternation; in the latter there would be a true concomitance.

The fifth section of Table II gives the frequencies of the "pure" heats that occur without any thermal concomitants. The frequency of the "pure" heats must decrease slightly with increasing separation, if we take the fourth section of Table II to mean that the concomitants—the "impure" heats—increase with the separation.

Psychology of Heat

Although we intended the introspections of our observers solely as a qualitative report upon our dual stimuli, we find in them considerable incidental material, which bears on the nature of localization of the heat and its spatial characteristics, upon the existence of fusion in heat or with heat, and upon the qualitative nature of heat itself. The reports make interesting psychological reading but limits of space forbid extended quotation from them. They are given in full in a bound manuscript report of this study which has been placed in the Clark University Library.[10]

Spatial Characteristics of Heat. Psychologically these heats, conditioned upon dual stimuli, are hard to localize although they have definite intrinsic spatial characteristics. B sought definitely to make a localization and ordinarily succeeded. P stated in his early trials that heat was unlocalizable but later indicated a number of spatial references. Y always had difficulty. Both P and Y repeatedly mention heats that are "unlocalizable." Such heats often occur in the presence of two definite pressures and yet can not be placed with respect to the pressures. The observers had, of course, no instruction to localize; nevertheless all three sought at times to do it. B, who was working with knowledge, undoubtedly sought to make the localizations because of their significance for the problem. His success may have been due to his greater effort and to his training in localization of organic processes.[11] Y sometimes, in his effort to localize heat in relation to the pressure-pattern on his arm, ended by locating the heat outside his body, altogether detached from the arm: "The heat was somewhere outside my arm" or "the heat was nowhere or detached from the body, and it was very small."

Heat is referred to a single place on the skin. In 411 heats obtained by our method of dual stimulation there were only three mentions of a "double heat." When heat is localized intentionally (B's reports) it may assume a definite relation to the spatial pattern of pressures.

[10] The Department of Experimental Psychology of Clark University proposes, in the case of studies where it is impossible to print detailed introspections or to give other data in full, to file a complete report as a bound manuscript in the Clark University Library. This report can be borrowed under the rules of the Library or loaned to other libraries under the usual courtesies of exchange. When a manuscript copy is a thesis and cannot be withdrawn, the Department proposes to deposit also a duplicate copy which may be allowed to circulate. Complete records that would be of value to other investigators are thus made available, while undue pressure upon the limited space in the psychological journals is avoided.

[11] *Cf.* Boring, The Sensations of the Alimentary Canal, this JOURNAL, 26, 1915, 1-57, esp. 38 f.

B found under such conditions that the heat was usually felt between the two pressures or connecting them. He reports: "Sometimes I localize heat as lines connecting the two pressures;" "localization is hard, and when I force it the heat gets itself localized as strands between the pressures;" "the heat stretches between the two points;" "the cold is localized above and the warmth below with the heat connecting them;" [13 such reports]. B also notes that the heat may occur between the two spots without connecting them: "The heat is near the upper pressure but displaced from it in the direction of the lower pressure;" "the heat lies in between the pressures of the two points where the warmth and cold are left respectively;" "the thermal complex lies in between the pressures, stretching toward them but not connecting them;" "by mistake I opened my eyes and could 'see' the heat arising on my arm midway between the two stimuli;" [10 such reports]. Occasionally, when the stimuli are close together, B finds the heat large and including the two pressures.

P and Y do not discover heats connecting the pressures or lying between them. Since localization is difficult, we may be inclined to attribute B's placing of heat in a position symmetrical to the two pressures to his effort to achieve a localization. On the other hand, P and Y occasionally do make localizations with respect to the pressures and always then place heat at one or the other spot. In these cases P always referred the heat to the cold spot [8 cases] and Y to the warm spot [4 cases].

None of the observers had difficulty in localizing warmth or cold with respect to the pressures or with respect to each other; and there are numerous cases in which an observer referred heat to a different spot from a concomitant cold or warmth. The relative localization of concomitant warmth and cold longitudinally upon the arm is nearly always objectively correct.

B and P always referred heat to the surface of the skin. Y uniformly reported it as "tridimensional," "penetrating," and as extending beneath the skin or entirely subcutaneous. The only exceptions to this rule are Y's report of heats detached from the body. Perhaps Y's subcutaneous reference of heat, like his report of "detached" heat, is due to his difficulty in localizing it. To report heat as detached from the body or as subcutaneous is to separate it spatially from the skin and thus from the impressions of pressure, warmth and cold, which are referred to the skin and which Y finds it difficult to bring into local relation to heat.

It appears that heat may be referred to the same region as a simultaneous warmth or to a different region, and to the same region as a simultaneous cold or to a different region. In exceptional cases concurrent warmth, cold and heat may all three be referred to the same region, or, as we have seen, may each be localized in a different place. We have no positive statement to make of the psychological nature of a heat that coincides with a warmth or a cold. One might expect that two qualities, temporally and spatially coincident, would necessarily fuse more or less perfectly after the manner of tones; and we shall see presently that fusions may occur.

Although difficult to localize, heat, nevertheless, appears in a definite spatial pattern. It may be clear-cut or diffuse, small or large, round or oval, even though the observer has difficulty in placing it with respect to other simultaneous sensory impressions or with respect to the habitual points of reference that he uses in localizing upon the arm. It is probable, as we have seen in B's case, that the effort to localize influences the spatial pattern. B, who alone succeeded often

in localizing, alone reports heat as large, diffuse or radiating. P and Y nearly always describe heat as small, clear-cut, and sharply defined. B also notes at times the occurrence of clear-cut small heats. We have shown above for B that a heat that connects two pressures or lies between them is diffuse or large, or is visualized as an oval or as strands connecting two pressures. The typical heat, however, is to be described as "very small," "smaller than cold," "1 mm. diam.," "a tiny patch," "a single point about 5 mm. diam.," "pointed," "clear-cut," "sharply defined," "narrowed down," "much smaller than warmth." A few reports mention heat as a tiny spot lying within a larger area of warmth.

Quality of Heat. Although our three observers agree that heat is a unique quality, they have not succeeded well in characterizing it. B, who had described it in Cutolo's experiment as "a quality lying between pressure and pain," continued in this conviction: "Heat is just the pressure-pain thing," "a drawing sensation similar to pressure," "normally heat is a simple pressure-sting," "heat was pressure-like in the way that ache is," "a pressure-aching quality developed into heat." Y laid especial emphasis upon the "brightness" of heat and B in certain reports agrees with him. By Y the appearance of "brightness" is repeatedly identified with the appearance of heat. P's characteristic adjective is "sharp;" he seems to mean by "sharp" something qualitative and not merely the spatial "pointedness" of heat.

Fusion. Physiologically heat is a fusion of the excitations normal to warmth and cold. We may ask, therefore, whether or not we find introspective evidence of this physiological fusion. The answer is that there are plenty of cases in which a simultaneous warmth and cold are observed to give place to ("fuse into") heat or in which a heat breaks up into a warmth and cold. The alternation of heat with warmth-and-cold indicates that in certain critical cases the physiological fusion may be instable.

Such phenomena, however, are not in themselves psychological fusions: they do not demonstrate a warmth and cold coexistent in heat. That heat may break up into warmth and cold may be due to a physiological instability or, on the other hand, it may be the result of an effort of attention to analyze it. These two cases are not necessarily distinct, for if the alternation is attentively conditioned it may constitute a case of analysis that is ordinarily taken as an evidence of psychological fusion. It would be crucial to determine whether the heat lapsed entirely in giving place to warmth and cold or merely became marginal, and whether, conversely, a marginal cold and warmth are to be discovered while heat is still focal. We are unable on the basis of our introspections to reach a conclusion here. P and Y never indicated fusions that could be taken to be psychological. B has but nine reports of a psychological fusion of warmth and cold in heat, and they do not indicate the exact nature of the concomitance: "A faint warmth and a faint cold were well fused, but not perfectly fused, into heat;" "there may be warmth and cold, or warmth or cold, in the heat, a very good fusion but perhaps not perfect; "heat, warmth and cold are simultaneous, but I can't attend to the heat and to the warm-cold at once;" "a poor heat in which the cold and warmth were not entirely lost though they became less prominent;" "cold-warmth or heat, an imperfect fusion." B has a great deal to say of the difficulty of attending to cold-warmth and to heat simultaneously when the possibility of attention to all is present. He seems to take this situation as indicative of fusion. Y noted warmth and cold as a back-ground to heat [once], heat as a

back-ground to warmth and cold [twice], and a simultaneous heat, warmth and cold, which he expressly denied as fusion [once]. P never indicated a fusion.

Cutolo remarks that heat may apparently form an imperfect psychological fusion with cold or with warmth alone, and our results are partially consistent with this conclusion. Most of the observations of such fusions are, however, for B, who was also Cutolo's observer. B has fourteen reports of a fusion of heat with cold and one only of a fusion of heat with warmth. P and Y do not unequivocally indicate these fusions. If such fusions normally occur in the heat-experience, they would indicate that the physiological fusion is partially but not completely represented in the psychological experience.

Heat and Cold. There is some indication that heat is more intimately related to cold than to warmth. We find (1) that heat and cold are both characteristically "bright." (2) B sometimes noted a pressure-like component in both heat and cold. (3) All observers agree that there is a qualitative similarity in some respect between heat and cold, although they also insist that the two sensations as totalities are notably different. (4) Heat and cold are alike in spatial pattern and (5) in temporal course. Both are small, clear-cut, and well defined, and both come in abruptly. Warmth, on the other hand, is typically diffuse, and indefinite in its initiation. (6) Cold is characteristically referred to the surface of the skin and warmth characteristically seems to well up from beneath the skin. B and P insist upon a superficial reference for heat, although Y refers heat beneath the skin. (7) Heat fuses psychologically more often with cold than with warmth [B's reports], and (8) seems more often to be referred to the cold spot [B's and P's reports] than to the warm spot. (9) Heat more often replaces cold in the thermal spatial pattern than warmth. No similar list of relationships of heat to warmth can be made out.

Conclusion

We conclude that heat is a physiological fusion of the excitations normal to warmth and cold. It may be aroused on the volar forearm by the adequate simultaneous stimulation of a warm spot and of an adjacent cold spot. The two spots may, however, yield a simple sensation of heat when separated by relatively great distances (10-15 cm.).

The resultant heat is difficult to localize. Sometimes, when localized, it appears to connect or to lie between the two points stimulated; sometimes it lies at one point or the other. Normally heat appears as small and sharply defined, but, when referred to a concomitant pressure-pattern, it may be large and diffuse. Heat may be localized at the same place as a concomitant warmth or cold or in a different place.

Rarely heat appears as an imperfect fusion of warmth and cold. More often it seems itself to fuse with cold. Frequently it replaces or gives place to a simultaneous warmth and cold.

Both psychologically and psychophysically heat seems to be more intimately related to cold than to warmth.

The quality of heat is unique and may be characterized as "bright." One observer finds heat qualitatively related to pressure and pain.